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On the role of extinction in failed gamma–ray burst optical/IR afterglows

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ABSTRACT

While all but one Gamma–Ray Bursts observed in the X–ray band showed an X–ray afterglow, about 60 per cent of them have not been detected in the optical band. We demonstrate that this is not due to adverse observing conditions, or delay in performing the observations. We also show that the optically non–detected afterglows are not affected by particularly large Galactic absorbing columns, since its distribution is similar for both the detected and non–detected burst subclasses. We then investigate the hypothesis that the failure of detecting the optical afterglow is due to absorption at the source location. We find that this is a marginally viable interpretation, but only if the X–ray burst and afterglow emission and the possible optical/UV flash do not destroy the dust responsible for absorption in the optical band. If dust is efficiently destroyed, we are led to conclude that bursts with no detected optical afterglow are intrinsically different. Prompt infrared observations are the key to solve this issue.

Key words: gamma rays: bursts — ISM: dust, extinction — radiation mechanisms: nonthermal

1 INTRODUCTION

The standard external shock synchrotron model (Meszaros & Rees 1997; Sari et al. 1998) has been very successful in describing the properties of observed optical afterglows (Wijers et al. 1997; Galama et al. 1998d, Covino et al. 1999). However, for more than half of the afterglows observed in the optical band we did not detect any emission. We will call these Failed Optical Afterglow (FOA) gamma–ray bursts. In all the gamma–ray burst error boxes promptly followed by narrow field X–ray instruments, an X–ray transient (afterglow) has been detected (with the only exception of GRB 990217), while only for $\sim$ 40 per cent of them optical observations have revealed an afterglow at optical wavelengths. This despite the rough similarity of the X–ray afterglow fluxes and the prompt reaction of optical telescopes. Paczynski (1998) ascribes this failed detection to dust extinction pointing out how this interpretation requires the association of bursts with star forming regions. If this is the case, infrared observations should be better suited for the hunt of afterglows, where the extinction plays a reduced role. For this reason, the IR follow–up of GRBs has recently become quite common, and some afterglows (GRB 990705, Masetti et al. 2000; and GRB 000418, Klose et al. 2000a) have been detected in the infrared before being confirmed at optical wavelengths. Yet, we still miss the detection of an IR afterglow without an optical counterpart: such a detection would confirm the role of dust in FOAs. Adding confusion to this picture, observations of extinction in X–ray spectra seem to reveal a very low gas to dust ratio (Vreeswijk et al. 1999, Galama & Wijers 2000) which, if common in all GRB environments, would strongly limit the role of dust extinction in the absorption of afterglows in the optical band and, even more, in the NIR.

In this paper we show that upper limits derived for FOAs are indeed not consistent with an "average afterglow", contrary to what recently claimed by Galama & Wijers (2000). We then analyze the properties of detected and non detected optical afterglows in order to check whether the absorption commonly seen in star forming regions can explain the large fraction of FOAs.

2 OBSERVATIONS

The first problem we face if we want to quantitatively describe the failed detection of afterglows is the extreme inhomogeneity of the sample. Different burst error boxes have been observed with different telescopes, with different depths, in different filters and at different times after the burst explosion. This situation makes extremely difficult even to understand whether FOAs are consistent with the brightness dispersion of the detected afterglows. We therefore attack the problem in two steps: first we ask whether

GRB	$F_{X,\rm NFI}$ 10^{-13}cgs	Δt_x h	δ_x	Ref	R	Δt_R h	δ_R	Ref	z	Ref
970228.12362	28±4	8	1.32	Co97	21.5±0.3	16.5	1.73±0.12	Ma98,Ga00	0.695	Bl98
970508.904	7±0.7	6	1.1	Am98	21.1±0.1	3.1	1.2[a]	Pe98,Ga98a	0.835	Me97
971214.97272	4±0.4	6.7	0.9	An97	22.06±0.06	13	1.20±0.02	Di98	3.418	Ku98
980326.88812	NP	—	—	—	21.25±0.03	11	2	Bl99	—	—
980329.1559	7.8±0.9	7	1.35	Za98a,b	20.8±0.3[b]	17	1.3±0.1	Re99	—	—
980425.90915[c]	4±0.6	10	0.2	Pi00a	15.7±0.1	59.8	—	Ga98b	0.0085	Ti98
980519.51403	1.4±0.3	9.7	1.8	Ni99	20.4±0.1	15.5	2.05±0.07	Ha99		
980613.20215	1.1±0.3	9	0.8	Co99a	22.9±0.2	16.3	1	Hj98,Dj98a	1.0964	Dj98b
990123.40780	110	5.8	1.35	He99a	18.26±0.04[d]	3.8	1.12±0.03	Od99,Ga99	1.6004	Ku99
990510.36743	14.7±1.8	8	1.4	Ku00	17.54±0.02	3.5	0.82±0.02	Hr99	1.619	Vr99a
990705.66765	1.9	11	1.6	Am00	16.57±0.05[e]	5.5	1.68±0.10	Ma00	—	—
990712.69655	NP	—	—	—	19.4±0.1	4.16	0.97±0.02	Sa00a	0.4331	Vr00
001011.66308	NP	—	—	—	20.6±0.1	8.4	1.4	Go00	—	—
980703.182468	7.5	22	1.3±0.25	Ga98c	21.00±0.09	22.6	1.39±0.3	Ca99a	0.9662	Dj98c
990308.21883	—	—	—	—	18.14±0.05	3.34	1.2±0.1	Sc99	—	—
991208.192269	—	—	—	—	18.7±0.1	49.9	2.15	Je99a	0.7055	Di99
991216.671544	1240±40	4.03	1.64	Ta99	18.49±0.05	10.8	1.22±0.04[f]	Ha00	1.02	Dj99
000131.62446	—	—	—	—	23.26±0.04	84.3	2.25±0.19	An00	4.50	An00
000301.41084	—	—	—	—	20.42±0.06	36.5	1.18±0.14	Sa00b	2.0335	Ca00a
000418.41921	—	—	—	—	21.63±0.04	59.3	0.86±0.06	Kl00	1.1854	Bl00
000630.02145	—	—	—	—	23.04±0.08	21.6	1.1±0.3	Je00	—	—
000911.30237	—	—	—	—	20.26±0.17	34.3	1.5±0.14	Pr00a,La00	—	—
000926.99274	4.8±0.7	48.2	4.3±1.0	Pi00b	19.37±0.02	20.7	1.36±0.11	Sa00c,Fy00a	2.066	Fy00b
001007.20749	—	—	—	—	20.3	83	0[g]	Ca00b,Pr00b	—	—

Notes: δ_ν is defined by $F_\nu(t) \propto t^{-\delta_\nu}$. X–ray fluxes in the 2–10 keV band. NP=repointing of *Beppo*SAX not possible. [a]: δ_R for $t > 2$days. [b]: I mag, R=23.6±0.2 after 20 hours. [c]: = SN 1998bw. [d]: Converted from Gunn r-mag. [e]: H mag. [f]: for t≤1.2 days. [g]: for t≤3.5 days, $\delta_R \sim 1.4$ after.

Am98: Amati et al., 1998; Am00: Amati et al., 2000 An97: Antonelli et al., 1997; An00: Andersen et al., 2000; Bl98: Bloom et al., 1998; Bl99: Bloom et al., 1999; Bl00: Bloom et al., 2000; Ca99a: Castro–Tirado et al., 1999a; Ca00a: Castro et al., 2000a; Ca00b: Castro et al., 2000b; Co97: Costa et al., 1997; Co99a: Costa et al., 1999a; Di98: Diercks et al., 1998; Dj98a: Djorgovski et al., 1998a; Dj98b: Djorgovski et al., 1998b; Dj98c: Djorgovski et al., 1998c; Dj99: Djorgovski et al., 1999; Do99: Dodonov et al., 1999; Fy00a: Fynbo et al., 2000a; Fy00b: Fynbo et al., 2000b; Ga98a: Galama et al., 1998a; Ga98b: Galama et al., 1998b; Ga98c: Galama et al., 1998c; Ga99: Galama et al., 1999; Ga00: Galama et al., 2000; Go00: Gorosabel et al., 2000; Ha99: Halpern et al., 1999; He99a: Heise et al., 1999; Hj98: Hjorth et al., 1998; Hr99: Harrison et al., 1999; Je99a: Jensen et al., 1999a; Je00: Jensen et al., 2000; Kl00: Klose et al., 2000a; Ku98: Kulkarni et al., 1998; Ku99: Kulkarni et al., 1999; Ku00: Kuulkers et al., 2000; La00: Lazzati et al., 2000; Ma98: Masetti et al., 1998; Ma00: Masetti et al., 2000; Me97: Metzger et al., 1997; Ni99a: Nicastro et al., 1999a; Od99: Odewahn et al., 1999; Pe98: Pedersen et al., 1998; Pi00a: Pian et al., 2000; Pi00b: Piro et al., 2000; Pr00a: Price et al., 2000a; Pr00b: Price et al., 2000b; Re99: Reichart et al., 1999; Sa00a: Sahu et al., 2000; Sa00b: Sagar et al., 2000a; Sa00c: Sagar et al., 2000b; Sc99: Schaefer et al., 1999; Ta99: Takeshima et al., 1999; Ti98: Tinney et al., 1998; Vr99a: Vreeswijk et al., 1999a; Vr00: Vreeswijk et al., 2000; Za98a: In't Zand et al., 1998a; Za98b: In't Zand et al., 1998b;

Table 1. Properties of the bursts with associated optical transient. The first 13 bursts have been observed by the *Beppo*SAX–GRBM/WFC, while the remaining bursts (below the horizontal line) have been discovered by other instruments (see text).

GRB	$F_{X,\mathrm{NFI}}$ 10^{-13}cgs	Δt_x h	δ_x	Ref	R	Δt_R h	Ref
970402.930	2.2±0.6	8	1.6	Ni98	21	18.5	Gr97a
971227.34938	2.6±0.6	14	1.12	An99a	22.8	21.3	Gr97b
981226.40793	5±1	11	1.3	Fr00	23	10.	Li99
990217.22462	< 1	6	>1.6	Pi99a	23.5	19.	Pa99a
990627.20894	3.5	8	—	Ni99b	21.	23.	Ro99
990704.7294	4.4±0.3	8	—	Fe99	22.5	4.6	Je99b
990806.60286	5.5±1.5	7.8	—	Fr99	22.	3.8	Vr99c
990907.7319	15±5	11	—	Pi99b	23.2[a]	24.9	Pa99b
990908.00125	NP	—	—	—	20.3[a]	11.5	Ax99
991014.9115	3.5±0.5	13	>0.4	Za00	22.6	12.9	Ug99
991105.69495	NP	—	—	—	23.5	16.	Pa99c
991106.4545	1.25±0.3	8	—	An99b	21.	9.1	Ca99b
000210.36396	4.5	7.2	—	Co99b	23.3	16.	Go00a,b
000214.042	2.75±0.9	12	0.6	An00	18.15[b]	32.4	Rh00
000424.76258	—	—	—	—	22.8	33.	Ug00
000528.36568	1.7±0.3	8.3	1	Ku00	23.3	18	Pa00a
000529.3361	2.8±0.7	7.5	—	Fe00	22.3	47	Pa00b
000615.2625	—	10	—	BS00	21.5	4.2	St00
000620.2317	—	—	—	—	19.8	5.7	Go00c
990520.08539	—	—	—	—	22[c]	19.5	Ma99
991217.17496	—	—	—	—	22.	11.	Mo99
000416.6062	—	—	—	—	20.7	50.3	Pr00c

Notes:NP=Repointing of *Beppo*SAX not possible; [a]: V mag. [b]: K mag. [c]: V mag.
An99a: Antonelli et al., 1999a; An99b: Antonelli et al., 1999b; An00: Antonelli et al., 2000; Ax99: Axwlrod et al., 1999; BS00: *Beppo*SAX mail No 00/18 = GCN Circ No 707; Ca99b: Castro–Tirado et al., 1999b; Co99b: Costa et al., 1999b; Fe99: Feroci et al., 1999; Fr99: Frontera et al., 1999; Fr00: Frontera et al., 2000; Go00a: Gorosabel et al., 2000a; Go00b: Gorosabel et al., 2000b; Go00c: Gorosabel et al., 2000c; Gr97a: Groot et al., 1997a; Gr97b: Groot et al., 1997b; Li99: Lindgren et al., 1999; Je99b: Jensen et al., 1999b; Ma99: Masetti et al., 1999; Mo99: Mohan et al., 1999; Ni98: Nicastro et al., 1998; Ni99b: Nicastro et al., 1998; Pa99a: Palazzi et al., 1999a; Pa99b: Palazzi et al., 1999b; Pa99c: Palazzi et al., 1999c; Pa00a: Palazzi et al., 2000a; Pa00b: Palazzi et al., 2000b; Pi99a: Piro et al., 1999a; Pi99b: Piro et al., 1999b; Pr00c: Price et al., 2000; Rh00: Rhoads eta l., 2000; Ro99: Rol et al., 1999; St00: Stanek et al., 2000; Ug99: Uglesich et al., 1999; Ug00: Uglesich et al., 2000; Vr99c: Vreeswijk et al., 1999c; Za00: in't Zand et al., 2000.

Table 2. Properties of the bursts with *Beppo*SAX–WFC detection but without associated optical transient. The last three bursts below the horizontal line refer to the γ–ray poor GRBs (or X–ray transients) detected by *Beppo*SAX.

the upper limits and reaction times in the case of FOAs are really inconsistent with what observed in optically detected afterglows, then we analyze the X–ray properties of both optical detections and non detections, to see if there is any difference.

Table 1 and Table 2 report the data of the bursts with and without a detected optical afterglow, respectively. We considered all bursts with an optically detected afterglow, irrespective if their locations has been provided by *Beppo*SAX (first 13 bursts in Table 1) or the IPN network and/or the XTE satellite (remaining bursts in Table 1). Instead, for FOAs, we have been more restrictive and have considered only those bursts detected by the WFC of *Beppo*SAX, which usually gives narrower error boxes, facilitating the search of an optical transient in the field of view. These data have been used to produce Figure 1, which shows the magnitudes of the optical afterglow detections and upper limits, all in the R band[⋆] versus the time of observation. Filled and empty circles correspond to *Beppo*SAX and non-*Beppo*SAX bursts with detected optical afterglows, while arrows are upper limits. The three X–ray transients tentatively associated with bursts (γ–ray poor GRBs, non significantly detected in the GRBM) are included in the sample of upper limits (however, their exclusion does not significantly influence any of the following results).

We have checked that local Galactic extinction does not play a crucial role by comparing the hydrogen column densities in the direction of detected afterglows with those in the direction of FOAs. Figure 2 shows the comparison. Applying a Kolmogorov–Smirnov (KS) test (Press et al. 1992), we obtain that the two distributions are drawn from the same parent population at the 94 per cent confidence level.

⋆ For those bursts that do not have any R band measurement, a spectrum $F(\nu) \propto \nu^{-1}$ has been assumed to transform V, I and H magnitudes in R magnitudes.

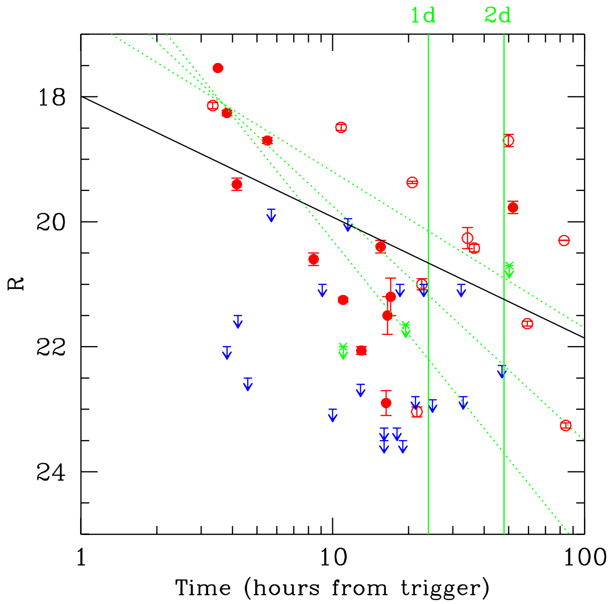

Figure 1. Detection R magnitude (or upper limits) versus the time of observation for a set of afterglows. Filled circles show optical detections of *Beppo*SAX afterglows while empty circles show detections of non *Beppo*SAX afterglows. Arrows show upper limits for *Beppo*SAX failed optical afterglows. Arrows with crosses refer to the upper limits on γ–ray poor X–ray transients detected by *Beppo*SAX. The dark solid line is the best fit for the magnitudes of detections vs. time. Dotted lines show the $F_\nu(t) \propto t^{-1}$, $t^{-1.5}$ and t^{-2} relations.

The visual inspection of Figure 1 reveals a clear segregation of arrows from dots, the former being systematically fainter than the latter at comparable times. The eye impression is confirmed by the application of a bidimensional KS test (Press et al. 1992). The probability for the circles (empty + filled) and the arrows being derived from the same parent distribution is $P \sim 0.2$ per cent.

This result shows that in most cases we failed to detect the optical afterglow not because the search was conducted without the necessary depth, but instead because the FOAs are indeed fainter than the detected ones. Yet, it is possible that FOAs are optically fainter because intrinsically less energetics at all wavelengths, or because they are more distant. In order to check this, we compared the X–ray and R band flux densities of bursts with and without optical detection 12 hours after the burst event. For bursts with optical detection, the magnitude at $t = 12$ h has been computed taking into account the measured flux decay with time while for FOAs an average $\delta_R = 1$[†] has been used.

The result is shown in Fig. 3, where dots correspond to detected afterglows while arrows indicate upper limits. In this figure, the number of points is smaller than in Fig. 1 because only those bursts with *Beppo*SAX NFI observations have been plotted, for consistency in the X–ray flux. We can see that the X–ray fluxes of FOAs are not systematically fainter than the fluxes of afterglows with optical detection, indicating that FOAs are indeed optically poor and define a different population with respect to optically detected afterglows.

Given this conclusion, we now explore the possibility that FOAs are intrinsically similar to bursts with detected optical afterglows, but suffer from dust extinction due to the propagation of their photons in a molecular cloud, where the burst explosion took place.

To this aim we need to quantify the required amount of extinction in the R band causing the optical afterglow to go undetected. There are two ways of doing this. A first way is to consider the ensambles of detections and upper limits, add a constant magnitude shift to all upper limits and recompute the KS probability until a maximum value is reached. This will give the average value of the extinction required to have an undetectable afterglow. This procedure gives an average absorption in the R band of $\langle A_R \rangle \sim 2.0$. Dereddening all FOAs by this amount maximizes the probability that all bursts belong to the same parent population (P ∼35 per cent).

To compute the fraction of FOAs with respect to all bursts we must use an homogeneous dataset. We then use only bursts detected by the WFC of *Beppo*SAX, excluding GRB 980425 and X–ray transients. We are left with 31 bursts, 19 of which are FOAs, yielding a fraction of 60 per cent. Therefore an average absorption of 2 magnitudes in the R band is needed for more than half of the bursts.

A different method to constrain the required absorption for FOAs is to estimate a burst–by–burst absorption by computing the lack of brightness with respect to an "average afterglow" R–t relation. The "average afterglow" relation is derived by a fit made on the sample of all detected optical afterglows. This gives:

$$R = 17.991 + 1.936 \log t \qquad (1)$$

where t is given in hours. This fit is shown in Figure 1 with a solid line.

The dotted line in Figure 4 shows the integrated distribution of the required A_R to bring each upper limit on the magnitude of FOAs to the magnitude given by Equation 1. X–ray transients have not been considered in this sample. Since it is not possible to quantify the local absorption that affects the detected bursts, we conservatively assume that their local absorption is negligible. The fact that the dotted line saturates for $A_R \leq 0.6$ is due to this assumption. If the optical afterglows of the detected bursts were locally absorbed, the dotted line would approach unity for A_R in the range shown in Fig. 4, making the discrepancy among the distributions even larger and then making a more compelling case.

3 ABSORPTION IN MOLECULAR CLOUDS

Absorption of several visual magnitudes in a molecular cloud is not uncommon, and hence the hypothesis that failed optical detections are due to absorption deserves a detailed analysis.

3.1 Average cloud absorption

As a first simple approach, we consider molecular clouds as uniform, with standard dust to gas ratios. A compilation

† The parameter δ is defined through $F_\nu(t) \propto t^{-\delta}$.

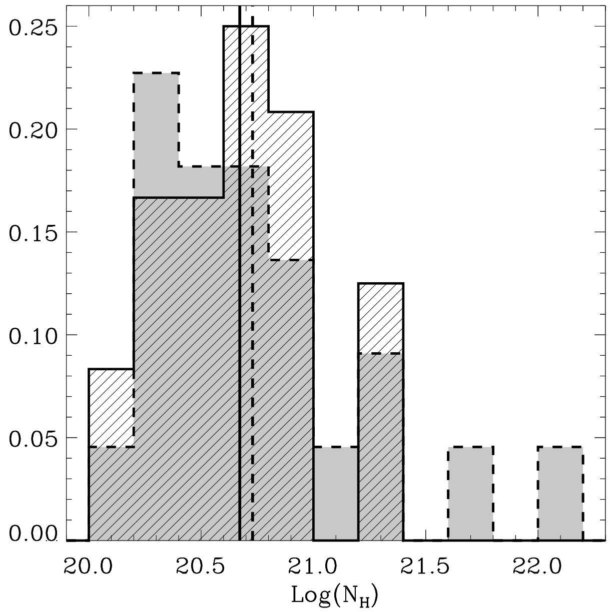

Figure 2. Logarithmic distribution of the column densities of bursts with (solid line and line shaded) and without (dashed line and grey shaded) optical afterglow. The distribution of bursts with afterglow includes both *Beppo*SAX and non *Beppo*SAX bursts. The vertical lines show the median value of the column density for bursts with (solid line) and without optical afterglow (dashed line). The two distributions can belong to the same parent population (at 94 per cent level, according to the KS test).

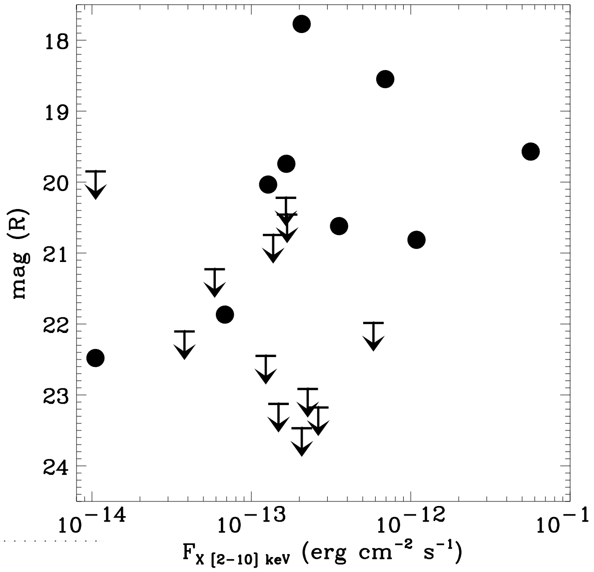

Figure 3. Optical R band magnitudes vs X–ray flux for *Beppo*SAX afterglows. Dots are afterglows with both optical and X–ray detections while arrows are upper limits for afterglows with X–ray detection but without any optical detection.

of Galactic cloud masses and sizes is given in Leisawitz et al. (1989), who analyze with a systematic survey the CO emission around 34 young open clusters of the Galaxy. We have computed the column density

$$N_{\rm H} = \frac{3\,M}{4\pi\, m_{\rm p}\, a_{\rm maj}\, a_{\rm min}} \quad (2)$$

where M is the mass of the cloud and $a_{\rm maj}$ and $a_{\rm min}$ are the major and minor axis of the cloud. For simplicity we have assumed that all the matter is in pure atomic hydrogen. This assumption implies that the derived $N_{\rm H}$ is slightly overestimated, but correct up to factors of order unity.

Analyzing the data of the same molecular clouds, Leisawitz (1990) derives a maximum observed column density of molecular hydrogen H_2 (note that a factor of two difference with $N_{\rm H}$ is expected for clouds with the same total mass) in each cloud. Clouds were observed through 3 to 144 lines of sight. Since the interstellar medium (ISM) in the clouds is not uniform, the maximum observed value is significantly larger than the derived average one (see Fig. 4) and may be a better statistical indicator of the column density where massive stars form.

3.2 The Orion molecular cloud

To better constrain the distribution of the expected extinctions within a single star–forming molecular cloud we have analyzed the observed extinction in O, B and A stars within the Orion molecular cloud. Data of E_{B-V} have been taken from Lee (1968), who gives the observed reddening for a sample of 196 stars. This reddening has been converted in absorption in the V band (A_V) by adopting the average shape parameter R_V appropriate for the environment close to hot, massive and young stars in the cloud (Lee 1968):

$$R_V \equiv \frac{A_V}{E_{B-V}} = 5.5 \quad (3)$$

from which $A_V = 5.5\, E_{B-V}$ (see also Sect. 4).

4 COMPARISON WITH AFTERGLOW (FAILED) OBSERVATIONS

In order to compare the absorption properties of (and in) the molecular clouds, as described above, with the R band absorption derived for FOAs, we must convert column densities and V band absorption in the R band.

To convert column densities into dust absorption, we adopt the dust to gas ratio given in Predehl & Schmitt (1995):

$$A_V = \frac{N_{\rm H}}{1.79 \times 10^{21} {\rm cm}^{-2}} \quad (4)$$

To convert dust absorption values from a wavelength to a different one, we use the analytic approximation for the dust extinction curve given in Cardelli et al. (1989).

A final problem is represented by the fact that we do not know the redshift of FOAs. Therefore we do not know at which rest frame wavelength we have to compute the extinction in the afterglow. In fact, what we observe in the R filter effective wavelength λ_R has been emitted (and dust extincted) at a rest frame wavelength $\lambda = \lambda_R/(1+z)$. As a *zero–order* assumption, we put all FOAs at a redshift $z = 1$, close to the average value of the detected afterglows. In this case we obtain $A_{R\,(z=1)} = 1.31\, A_V$.

By adopting all the corrections described above, we can

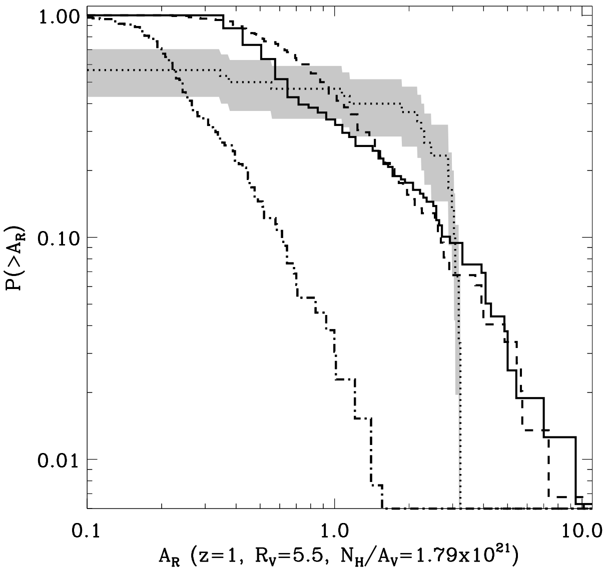

Figure 4. Comparison between the estimated absorption in FOAs and the absorption expected from molecular clouds. Lines show the integral distribution of the R band absorption for the average column density in molecular clouds (dot–dashed); for the peak column density in molecular clouds (dashed) and for stars in Orion (solid). See text for the conversion of $N_{\rm H}$ and A_V in $z=1$ R band absorption. The dotted line shows the integral distribution of the lower limits of A_R for FOAs, while the shaded area is the $1\,\sigma$ confidence region.

convert the average $N_{\rm H}$, the peak $N_{\rm H_2}$ and the A_V values of molecular clouds into a distribution of expected R band extinctions for a burst at redshift $z=1$. Figure 4 shows the result of this conversion: the dot–dashed line shows the integral distribution of A_R values as derived from the average $N_{\rm H}$ of Galactic molecular clouds. The dashed line shows the integral distribution of A_R as derived from the distribution of the peak value of N_{H_2} in the same clouds, while the solid line shows the integral distribution derived from A_V absorption of hot stars in the Orion molecular cloud.

In order to compare the absorption required to obscure FOAs with the distributions in Figure 4, we consider first the average $\langle A_R \rangle$ inferred for the bursts as a sample.

As detailed in Section 2 we need that 60 per cent of the lines of sight to bursts are affected by 2 magnitudes of absorption.

Fig. 4 shows that if we use the average value of $N_{\rm H}$ of the clouds, $A_R > 2$ only in the ∼0.8 per cent of the cases, while if we use the peak value of $N_{\rm H}$ this fraction increases to ∼15 per cent. We also have that ∼18 per cent of the hot stars in Orion have $A_R > 2$. Note that all these values refer to the absorption estimated in the observed R band, but assuming that the sources are at $z=1$.

These results imply that even if FOAs are located in the most absorbed regions of molecular clouds, in several cases the corresponding absorption is not enough to hide their optical afterglows. Given our assumptions, the statistical significance of this result is $\geq 3\,\sigma$: admittedly not extremely compelling, but consider that we have used upper limits to measure the amount of A_R, which could then be much larger.

Besides the integral distributions of A_R observed in molecular clouds, Fig. 4 shows (dotted line) the integral distribution of the lower limits on A_R derived for FOAs, with the gray shaded area corresponding to the $1\,\sigma$ confidence region for the same distribution.

The large negative deviations of the high and low absorption tails are due to the intrinsic limitations of the lower limits sample, but the difference around $A_R \sim 2$ with respect to the solid line is real, even if significant at the $\geq 2\,\sigma$ level only. This, again, shows that the required absorption is larger than the absorption associated on average to a molecular cloud at redshift $z=1$.

5 DISCUSSION

By analyzing the properties of detected optical and X–ray afterglows and the upper limits for failed detections, we show that the subset of bursts without optical afterglow (FOAs) defines a different family. We have investigated if this can be due to dust extinction of optical radiation in a molecular cloud. We find that this hypothesis can only marginally account for the large fraction of FOAs, and therefore we cannot exclude the possibility that FOAs are intrinsically less luminous in the optical/UV band with respect to the detected ones, and with respect to their own X–ray luminosity.

Consider also that we have been very conservative in our procedure, because our results are based on considering *upper limits* on the optical flux, and *peak* absorption columns expected in giant molecular clouds. The latter assumptions may well be too conservative, if the dust is bound to evaporate when illuminated and heated by the powerful optical/UV flash of the gamma–ray burst (Waxman & Draine 2000) and by its X–ray radiation (Fruchter et al. 2000). This dust sublimation is suggested for a sample of burst afterglows (Vreeswijk et al. 1999c, Galama & Wijers 2000), in which a very large hydrogen column density $N_{\rm H} \gtrsim 10^{22}$ cm^{-2}, as estimated by X–ray data, is associated with almost no optical extinction. The results can be understood only in terms of a dust to gas ratio ∼ 100 times smaller than the Galactic average value. In turns, such low values of the dust to gas ratio can be explained only if the dust has been completely sublimated in the surroundings of the burst. Indeed the theoretical models mentioned above predict that dust can be destroyed by the burst emission out to a radius comparable to the dimension of a typical molecular cloud (up to a few tens of parsecs). If this is the case, the material responsible for absorption in FOAs is not the overdense cocoon surrounding the star forming region, but the cloud as a whole (or even less), and the discrepancy between the observed and measured value (see dash-dotted line in Fig. 4) becomes extremely compelling.

An interesting way to assess whether dust is playing any role in FOAs is to perform near infrared (NIR) follow–up of their γ or X–ray error boxes. For instance, in the K filter, absorption is greatly reduced, so that only a very small fraction (less than 10 per cent) of afterglows should show more than 1 magnitude of absorption, in any of the adopted cloud models. This is therefore a crucial test to understand whether FOAs are due to dust absorption (less severe in the near infrared) or to an intrinsic difference in the emitted spectrum (that should be more severe in the NIR). Some

FOAs have been indeed looked for in the NIR band, but the observations are still very sparse and we lack any statistics to draw any meaningful conclusion.

NIR observations are thus strongly recommended as the key test for the dust extinction hypothesis, especially after the launch of HETE II, which will rapidly distribute accurate enough locations of bursts to be promptly followed by ground based telescopes. A more homogeneous dataset, though, will have to await the launch of the Swift satellite, foreseen in 2003. The systematic follow–up with the on–board optical telescope will provide a multiband spectroscopic database of the first hours of optical afterglows. Data of even higher quality could be achieved if IR robotic telescopes (such as the one proposed by the consortium of Brera, Rome and Catania Observatories, called REM, for Rapid Eye Mount), will be in operation to complement Swift observations from the ground.

A possibility to increase the absorption in the observed R band without invoking particularly dense molecular clouds is by allowing for a higher redshift of the bursts. This would make the afterglow undetectable, especially if the redshift of the burst is particularly high ($z \gtrsim 4$), so that the redshifted Lyman α break falls in the R filter. In this case, again, near infrared (JHK) observations should be unaffected by absorption and the optical transient easily detectable. Estimates of the fraction of high redshift GRBs (see, e.g., Porciani & Madau 2000) predict however a very small fraction of bursts (up to few per cent) at $z > 3$, if the GRB and star–formation rate are related.

In conclusion, we have found that dust absorption is not a completely satisfying explanation for bursts without a detected optical afterglow, and we cannot rule out the possibility that they are due to an intrinsic larger dispersion of optical fluxes with respect to the dispersion of the X–ray fluxes (see also Böer & Gendre 2000).

This, in turn, opens some exciting observational perspectives aiming to disclose the nature of the burst progenitor: if bursts are indeed associated with the final stages of stellar evolution and a supernova–like event is associated to all bursts, then the search for supernova signatures should be easier for bursts with an optical faint afterglow, for which the SN lightcurve would not be polluted by the flux of the afterglow. If we assume SN1998bw (Galama et al. 1998c) as a template supernova lightcurve, the expected magnitudes at maximum should be roughly $I = 24$ and $R = 25$, easily detectable with a signal to noise ratio of ~ 10 with an exposure time of only ~ 10 min with an 8 meter class telescope.

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REFERENCES

Amati L. et al., 2000, Science, Nov 3 issue

Amati L. et al., 1998, in The Active X-ray Sky: Results from *Beppo*SAX and RXTE. Edited by L. Scarsi, H. Bradt, P. Giommi & F. Fiore. Nuclear Physics B, (Proc. Suppl.), vol. 69/1-3, p. 656

Andersen M.I. et al., 2000, A&A, in press (astro-ph/0010322)

Antonelli L.A., Butler R.C., Piro L., Celidonio G., Coletta A., Tesseri A., De Libero C., 1997, IAUC 6792

Antonelli L.A. et al., 1999a, A&AS, 138, 435

Antonelli L.A. et al., 1999b, GCN Circ No 445

Antonelli L.A. et al., 2000 ApJ in press, (astro–ph/0010221)

Axelrod T., Mould J. & Schmidt B., 1999, GCN Circ. No 408

Bloom, J.S., Djorgovski, S.G., Kulkarni, S.R., Frail, D.A., 1998, ApJ, 507, L25

Bloom, J.S. et al., 1999, Nature, 401, 453

Bloom J.S., Diercks A., Djorgovski S.G, Kaplan D. & Kulkarni S.R., 2000, GCN Circular, No 661

Böer M. & Gendre B., 2000, A&A in press (astro-ph/0008385)

Cardelli J. A., Clayton G. C. & Mathis J. S., 1989, ApJ, 345, 245

Castro–Tirado A.J. et al., 1999a, ApJ, 511, L85

Castro–Tirado A., Gorosabel J., Rodriguez E., Sanchez del Rio J., Vanderiest C., Proust D. & Feroci M., 1999b, GCN Circ. No 436

Castro–Tirado S.M., Diercks A., Djorgovski S.G., Kulkarni S.R., Galama T.J., Bloom J.S., Harrison F.A. & Frail D.A., 2000a, GCN Circ No 605

Castro–Tirado S.M. et al., 2000b, GCN Circular, No 845

Costa E. et al., 1997, Nature, 387, 783

Costa E. et al., 1999a, IAUC 6939

Costa E. et al., 1999b, GCN Circ No 553

Diercks A.H. et al., 1998, ApJ, 503, L105

Covino S. et al., 1999, A&A, 348, L1

Djorgovski S.G., Kulkarni S.R., Odewahn S.C. & Ebeling H., 1998a, GCN Circular, No. 117

Djorgovski S.G., Kulkarni S.R., Bloom J.S, Frail D., Chaffee F. & Goodrich R. 1998b, GCN Circ No. 189

Djorgovski S.G., Kulkarni S.R., Bloom J.S., Goodrich R., Frail D.A., Piro L. & Palazzi E, 1998c, ApJ, 508, L17

Djorgovski S.G. Goodrich R., Kulkarni S.R., Bloom J.S., Dierks A., Harrison F., & Frail D.A., 1999, GCN Circ No. 510

Dodonov S.N., Afanasiev V.L., Sokolov V.V., Moiseev A.V. & Castro-Tirado A.J., 1999, GCN Circ No. 475

Feroci M. et al., 1999, IAUC 7217

Feroci M. et al., 2000, GCN Circ No 685

Frontera F. et al., 2000, ApJ, 540, 697

Frontera F. et al., 1999, IAUC 7235

Fruchter A.S., Krolik J. & Rhoads J., 2000, ApJ submitted

Fynbo J.P.U, Moller P, Gorosabel J., Hjorth J., Jensen B.L. & Pedersen H., 2000a, GCN Circular, No. 825

Fynbo J.P.U., Moller P., Dall T., Pedersen H., Jensen B.L., Hjorth & Gorosabel J., 2000b, GCN Circular, No. 807

Galama T.J. et al., 1998a, ApJ, 497, L13

Galama T.J., Vreeswijk P.M., Frontera F., Doublier V.& Gonzalez J.F., 1998b, IAUC 6895

Galama T.J, Vreeswijk P.M., van Paradijs J., Kouveliotou C., Antonelli L.A., Torroni V., Pastor C., 1998c, GCN No. 145

Galama T.J. et al., 1999, Nature, 398, 394

Galama T.J. et al., 2000, ApJ, 536, 185

Galama T. J., et al., 1998c, Nature, 395, 670

Galama T. J., Wijers R. A. M. J., Bremer M., Groot P. J., Strom R. G., Kouveliotou C. & Van Paradijs J., 1998d, ApJ, 500, L97

Galama T. J. & Wijers R. A. M. J., 2000, ApJ submitted (astro-ph/0009367)

Gorosabel J. et al., 2000, GCN Circ No 849

Gorosabel J. et al., 2000a, GCN Circ No 545

Gorosabel J. et al., 2000b, GCN Circ No 547

Gorosabel J. et al., 2000c, GCN Circ No 734

Groot P.J. et al, 1997a, IAUC 6616

Groot P.J. et al, 1997b, GCN Circ No 17

Halpern J.P., Kemp J., Piran T. & Bershady M.A., 1998, ApJ, 517, L105
Halpern J.P. et al., 2000, ApJ in press (astro-ph/0006206)
Harrison F.A. et al., 1999, ApJ, 523, L121
Heise J., DeLibero C., Daniele M.R., Scotti G.,Ricci D., Capalbi M., Antonelli L.A. & Costa E., 1999a, IAUC 7099
Hjorth J., Andersen M.I., Pedersen, H., Jaunsen A.O., Costa E. & Palazzi E., 1998, GCN Circ No 109
In't Zand J.J. et al., 1998a, IAUC 6854
In't Zand J.J. et al., 1998b, ApJ, 505, L119
In't Zand J.J.M. et al., 2000, submitted to ApJ (astro–ph/0007280)
Jensen B.L, Hjorth J., Pedersen H., Kristen H.E., Tomassi L., Pian E. & Hurley K., 1999a, GCN Circ No 454
Jensen B.L. et al., 1999b, GCN Circ. no 371
Jensen B.L., Fynbo J.P.U., Pedersen H., Hjorth J., Gorosabel J., Delgado D.G., Schwarz H. & Henden A., 2000, GCN Circular, No. 747
Klose S. et al., 2000a, ApJ in press (astro-ph/0007201)
Klose S. et al., 2000b, GCN Circ No 713
Kulkarni S.R. et al., 1998b, Nature, 395, 663
Kulkarni S.R. et al., 1999, Nature, 398, 389
Kuulkers E. et al., 2000, ApJ, 538, 638
Lazzati D., Covino S., Fugazza D., Ghisellini G., 2000, GCN Circ No 822
Lee T. A., 1968, ApJ, 152, 913
Leisawitz D., Bash F. N. & Thaddeus P., 1989, ApJS, 70, 731
Leisawitz D., 1990, ApJ, 359, 319
Lindgren B. et al., GCN Circ. No 190
Masetti N., Bartolini C. Guarnieri A. & Piccioni A., 1998, in The Active X-ray Sky: Results from *Beppo*SAX and RXTE. Edited by L. Scarsi, H. Bradt, P. Giommi, & F. Fiore. Nuclear Physics B, (Proc. Suppl.), vol. 69/1-3, p. 674
Masetti N. et al., 2000, A&A 354, 473
Masetti N. et al., 1999, GCN Circ No 345
Meszaros P. & Rees M. J., 1997, ApJ, 476, 232
Metzger M.R., Djorgovski S.G., Kulkarni S.R., Steidel C.C., Adelberger K.L., Frail D.A., Costa E. & Frontera F., 1997, Nature, 387, 878
Mohan V., Sagar R., Pandey A.K., Gorosabel J. & Castro–Tirado A.J., 1999, GCN Circ No 502
Nicastro L. et al., 1998, A&A, 338, L17
Nicastro L. et al., 1999a, A&AS, 138, 437
Nicastro L. et al., 1999b, IAUC 7213
Odewahn S.C., Bloom J.S. & Kulkarni S.R., 1999, CGN No. 201
Paczynski B., 1998, ApJ, 494, L45
Palazzi E. et al., 1999a, GCN Circ No 262
Palazzi E. et al., 1999b, GCN Circ No 413
Palazzi E. et al., 1999c, GCN Circ No 449
Palazzi E. et al., 2000a, GCN Circ No 691
Palazzi E. et al., 2000b, GCN Circ No 699
Pedersen H. et al., 1998, ApJ, 496, 311
Pian E. et al., 2000, ApJ, 536, 778
Piro L. & Antonelli L.A., 2000, GCN Circ No. 832
Piro L., Capalbi M., Ricci R., Dadina M., Di Ciolo L., De Libero C. & Butler R.C., 1999b, GCN Circ No 409
Piro L. et al., 1999, IAUC 7111
Porciani C. & Madau P., 2000, ApJ in press (astro-ph/0008294)
Predehl P. & Schmitt J.H.M.M., 1995, A&A, 293, 889
Press W.H., Teukolsky S.A., Vetterling W.T. & Flannery B.P., 1992, Numerical recipes (second edition), Cambridge University Press
Price P.A., Galama T.J., Goodrich R.W. & Diercks A., 2000a, GCN Circ No 796
Price P.A., Pevunova O., Madore B., Djorgovski S.G., 2000b, GCN Circ No 862
Price P., Axelrod T. & Schmidt B., 2000c, GCN Circ. No 640
Reichart D.E. et al., 1999, ApJ, 517, 692
Rhoads J., Wilson A., Storchi-Bergmann T. & Fruchter A., 2000, GCN Circ No 564
Rol E. et al., 1999, GCN Circ No 358
Sagar R., Mohan V., Pandey S.B., Pandey A.K., Stalin C.S. & Castro-Tirado A.J., 2000a, BASI, 28, 499
Sagar R., Pandey S.B., Mohan V., Bhattacharya D. & Casto–Tirado A.J., 2000b, subm. to Bull. Astr. Soc. India (astro-ph/0010212)
Sahu K.C. et al., 2000, ApJ, 540, 74
Sari R., Piran T. & Narayan R., 1998, ApJ, 497, L17
Schaefer B.E. et al., 1999, ApJ, 524, L103
Stanek K.Z., Garnavich P.M., Jha S. & Berlind P., 2000, GCN Circ No 709
Takeshima T., Markwardt C., Marshall F., Giblin T. & Kippen R.M., 1999, GCN Circ No 478
Tinney C., Stathakis R., Cannon R. & Galama T., 1998, IAUC 6896
Uglesich R., Halpern J.P. & Thorstensen J., 1999, GCN Circ No 428
Uglesich R., Mirabal N., Halpern J.P., Vanlandingham K., Noel-Storr J., Wagner R.M. & Eskridge P., 2000, GCN Circ No 663
Vreeswijk P.M. et al., 1999a, GCN Circ No 324
Vreeswijk P. M. et al., 1999b, ApJ, 523, 171
Vreeswijk P.M. et al., 1999c, GCN Circ No 398
Vreeswijk P.M. et al., 2000, ApJ in press (astro–ph/0009025)
Waxman E. & Draine B. T., 2000, ApJ, 537, 796
Wijers R. A. M. J., Rees M. J. & Meszaros P., 1997, MNRAS, 288, L51